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FLIGHT INVESTIGATION AT HIGH SPEEDS OF PROFILE DRAG OF WING OF A P-47D AIRPLANE HAVING PRODUCTION SURFACES COVERED WITH CAMOUFLAGE PAINT

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FLIGHT INVESTIGATION AT HIGH SPEEDS OF PROFILE DRAG OF WING OF A P-47D AIRPLANE HAVING PRODUCTION SURFACES COVERED WITH CAMOUFLAGE PAINT

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SUMMARY

A flight investigation was made at high speeds to determine the profile drag of a P-47D airplane wing having production surfaces covered with camouflage paint. The profile drag of a wing section somewhat outboard of the flap was determined by means of wake surveys in tests made over a range of airplane lift coefficients from 0.06 to 0.69 and airplane Mach numbers from 0.25 to 0.78.

The results of the tests indicated that a minimum profile-drag coefficient of 0.0097 was attained for lift coefficients from 0.16 to 0.25 at Mach numbers less than 0.67. Below the Mach number at which compressibility shock occurred, variations in Mach number of as much as 0.2 appeared to have no effect on profile-drag coefficient. The variation in Reynolds number corresponding to this variation in Mach number, however, was appreciable and may have had some effect on the results obtained. Comparison of the Mach number at which shock losses were first evident in the wake with the critical Mach number indicated that shock was not evident until the critical Mach number was exceeded by at least 0.025.

INTRODUCTION

A flight investigation was made to determine the profile-drag characteristics of a P-47D airplane wing with various surface finishes. Two phases of this investigation were reported in references 1 and 2, and the third and last phase is reported herein. In reference 1 results were reported of tests made to determine boundary-layer-transition locations and profile drag of a wing section with faired and smoothed surfaces. In reference 2 results were reported of tests made to determine the effect of surface roughness on the profile drag of the faired surfaces with transition fixed far forward. The results reported herein are of tests made to determine the profile drag of a wing section having unfaired production surfaces covered with camouflage paint. The present tests and those of references 1 and 2 included Mach numbers through the critical values; in the present tests, however, the Mach number range was extended to somewhat higher supercritical values than those of references 1 and 2.

Profile drag was determined by means of wake surveys. The tests were made for conditions in which airplane lift coefficients from 0.06 to 0.69, Reynolds numbers from 8.4×10^6 to 23.1×10^6, and Mach numbers from 0.25 to 0.78 were obtained.

APPARATUS AND TESTS

The investigation was conducted on a right wing section of a P-47D airplane (fig. 1). This wing section, a Republic S-3 section, had a chord of 86.05 inches, a thickness of 11 percent of the chord, and was located at 63 percent of the semispan from the plane of symmetry, or about 2 feet outboard of the flap. At this spanwise station the test section included the aileron but was outboard of the propeller slipstream, the gun ports in the leading edge, and the shell ejector slots in the lower surface. The measured ordinates of the test section are given in fractions of the chord in table I. The Republic S-3 section tested has pressure-distribution characteristics similar to those of the NACA 23011 airfoil.

The surfaces of the test section were prepared by covering the production surfaces with one coat of zinc chromate primer, one coat of gray surfacer, and two coats of olive-drab camouflage paint. Measurements of surface roughness made by means of a shop microscope (described in reference 2) indicated that the surface roughness consisted of particles of about 0.0012 inch in height and numbering roughly 10,000 per square inch.

An indication of surface waviness was obtained by means of a curvature gage (fig. 2) with legs spaced 4 percent of the test section chord. The waviness condition of the unfaired and roughened production surfaces and also of the faired and smoothed surfaces of reference 1 is indicated in figure 4 by the plot of the waviness index d/c against s/c, where d is the deflection of the curvature gage, s is the distance along the surface from the leading edge, and c is the test section chord.

Profile-drag measurements were made with a wake-survey rake (fig. 3) located 19 percent of the chord behind the trailing edge of the test section. The rake was the same as that used in references 1 and 2 except that two tubes spaced four inches were added to each end of the rake (making a total width of 23.9 inches) in order to permit a survey of more of the wake at supercritical speeds than in references 1 and 2. Wake total and static pressures, free-stream impact pressure, and the position of the right aileron were measured with NACA recording instruments. The section profile-drag coefficients c_{d_o} were determined by the integrating method of reference 3; that is, the total-pressure loss was integrated across the wake and then multiplied by factors depending on free-stream impact pressure, maximum total-pressure loss, static pressure in the wake, and flight Mach number.

The tests were made in level flight, dives, and turns at 20,000 feet and over a range of calibrated airspeeds from 150 to 415 miles per hour. The airplane lift coefficient C_L obtained in the tests ranged from 0.06 to 0.69, the Reynolds number R from 8.4×10^6 to 23.1×10^6 and the Mach number M from 0.25 to 0.78.

RESULTS AND DISCUSSION

The investigation of flow conditions indicated by surface tufts located over a portion of the upper surface of the P-47D airplane wing, reported in reference 4, showed that somewhat inboard of the test section, at 63 percent semispan, cross flow was present at Mach numbers greater than 0.70 at a lift coefficient of 0.40 and greater than 0.76 at a lift coefficient of 0.15. Because of this flow condition and the fact that the wake at Mach numbers greater than 0.66 at a lift coefficient of 0.40 and greater than 0.72 at a lift coefficient of 0.15 extended beyond the limits of the wake-survey rake, the wake surveys for these flight conditions were not evaluated.

Profile-drag coefficients selected for several lift coefficients for which the data were most complete are plotted against Mach number in figure 5. The corresponding Reynolds numbers are plotted above the profile-drag curves.

Figure 5 shows that the profile-drag coefficient decreased with lift coefficient and attained a minimum value of 0.0097 over a range of lift coefficients from at least 0.16 to 0.25 at Mach numbers below 0.67. The minimum value of the profile-drag coefficient of the faired and smoothed surfaces reported in reference 1 was 0.0062. At Mach numbers below that at which compressibility shock was evident, as indicated by the rapid increase in profile-drag coefficient, variation in Mach number of as much as 0.2 appeared to have no effect on the profile-drag coefficient. This variation in Mach number, however, was accompanied by an appreciable variation in Reynolds number, which may have had some effect on the results obtained. In the tests of references 1 and 2 variations in Mach number of as much as 0.16, with negligible variation in Reynolds number, had no effect on the profile-drag coefficient for the wing section with smooth surfaces and for the wing section with smooth and rough surfaces with transition fixed far forward.

The flight Mach number and airplane lift coefficient at which compressibility shock losses became evident in the wake are shown by figure 6. The rapidly increasing width of wake with Mach number is shown in figure 7 as an indication of the presence of compressibility shock losses in the wake. In this figure the total-pressure loss across the wake is presented for several Mach numbers at a lift coefficient of about 0.16 as a plot of $\Delta H/q_c$ against y/c, where ΔH is the loss in total pressure at position y in the wake, q_c is the free-stream impact pressure, and c is the chord of the wing section. (Position $y/c = 0$ corresponds to the top tube of the rake.) Wake profiles for Mach numbers 0.64 and 0.67 showed no evidence of shock, but profiles for Mach numbers 0.68, 0.70, and 0.78 indicated shock of increasing intensity on the upper surface.

In figure 6 the demarcation of flight conditions with respect to the presence or absence of shock losses in the wake is well defined. At lift coefficients of 0.10 and 0.50, shock was first indicated at Mach numbers 0.69 and 0.62, respectively. The first indications of shock in the wake as shown by figure 6 correspond to the beginning of the rapid increase in profile-drag coefficients in figure 5.

The critical Mach number for the wing section having production surfaces covered with camouflage paint was not determined. The critical Mach number, for the corresponding left wing section with faired and smoothed surfaces, however, was determined in tests reported in reference 1. This critical Mach number, shown plotted in figure 6, may be as much as 0.03 too high for the present tests because of the method of measuring the chordwise pressure distribution and because the left aileron was deflected upward about 3° and the right aileron was deflected downward about 1°. Comparison of the Mach number at which shock was first evident in the wake with this critical Mach number indicates that shock losses were not evident in the wake until the critical Mach number was exceeded by at least 0.025. A similar result was obtained in references 1 and 2 except that, in reference 1 for the faired and smooth wing section, the critical Mach number was exceeded by at least 0.04. The appearance of shock in the wake of the unfaired and roughened production surfaces at a lower Mach number than for the faired and smooth surfaces may be associated with a lower critical Mach number for the unfaired and roughened production surfaces than for the faired and smooth surfaces.

CONCLUSIONS

The flight investigation of the profile drag of a P-47D airplane wing having production surfaces covered with camouflage paint indicated the following results:

1. A minimum profile-drag coefficient of 0.0097 was attained for airplane lift coefficients from 0.16 to 0.25 at Mach numbers below 0.67.

2. Below the Mach number at which compressibility shock was evident, as indicated by rapid rise in profile-drag coefficient, variation in Mach number of as much as

0.2 appeared to have no effect on profile-drag coefficient. The variation in Reynolds number that corresponded to this variation in Mach number was appreciable and may have had some effect on the results obtained.

3. Comparison of the Mach number at which shock losses were first evident in the wake with the critical Mach number of the wing section with faired and smooth surfaces indicated that compressibility shock losses were not evident until the critical Mach number was exceeded by at least 0.025.

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REFERENCES

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2. Zalovcik, John A., and Wood, Clotaire: A Flight Investigation of the Effect of Surface Roughness on Wing Profile Drag with Transition Fixed. NACA ARR No. L4L25, 1944.

3. Silverstein, A., and Katzoff, S.: A Simplified Method for Determining Wing Profile Drag in Flight. Jour. Aero. Sci., vol. 7, no. 7, May 1940, pp. 295-301.

4. Wood, Clotaire, and Zalovcik, John A.: Flight Investigation at High Speeds of Flow Conditions over an Airplane Wing as Indicated by Surface Tufts. NACA CB No. L5E22, 1945.

TABLE I

ORDINATES OF REPUBLIC S-3 WING SECTION TESTED

ON P-47D AIRPLANE

[All values given in fractions of chord; ordinates measured relative to an arbitrary chord and with inboard trailing edge of aileron in line with trailing edge of flap]

Station	Ordinate	
	Upper surface	Lower surface
0	0	0
.0125	.0192	-.0093
.0250	.0310	-.0134
.0500	.0444	-.0184
.0750	.0535	-.0221
.10	.0604	-.0253
.15	.0674	-.0308
.20	.0706	-.0354
.25	.0711	-.0381
.30	.0705	-.0395
.35	.0685	-.0400
.40	.0656	-.0395
.45	.0627	-.0378
.50	.0589	-.0356
.60	.0485	-.0296
.70	.0354	-.0221
.80	.0230	-.0156
.90	.0105	-.0060
1.00	0	0
L.E. radius: 0.0087		

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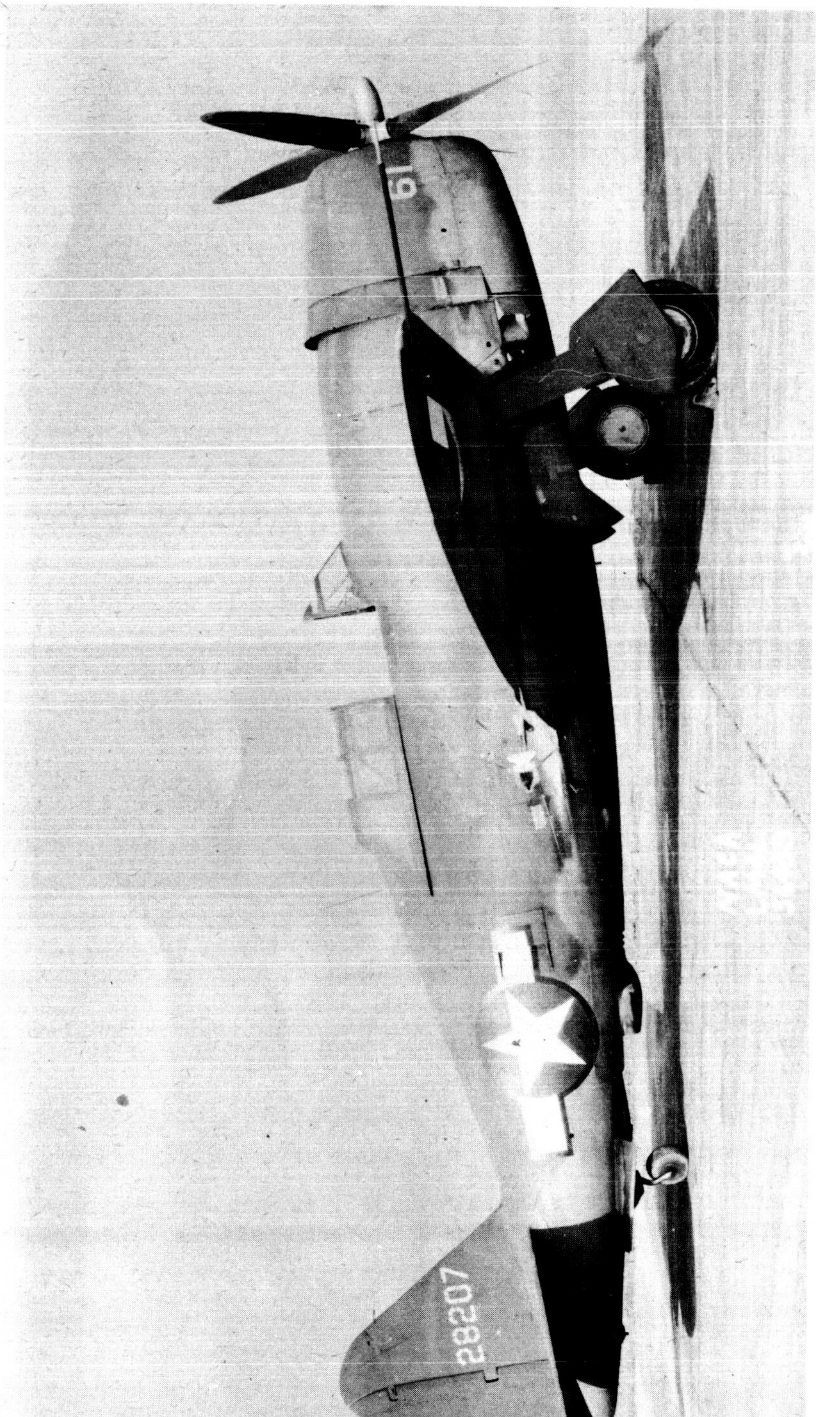

Figure 1.- P-47D airplane used for tests.

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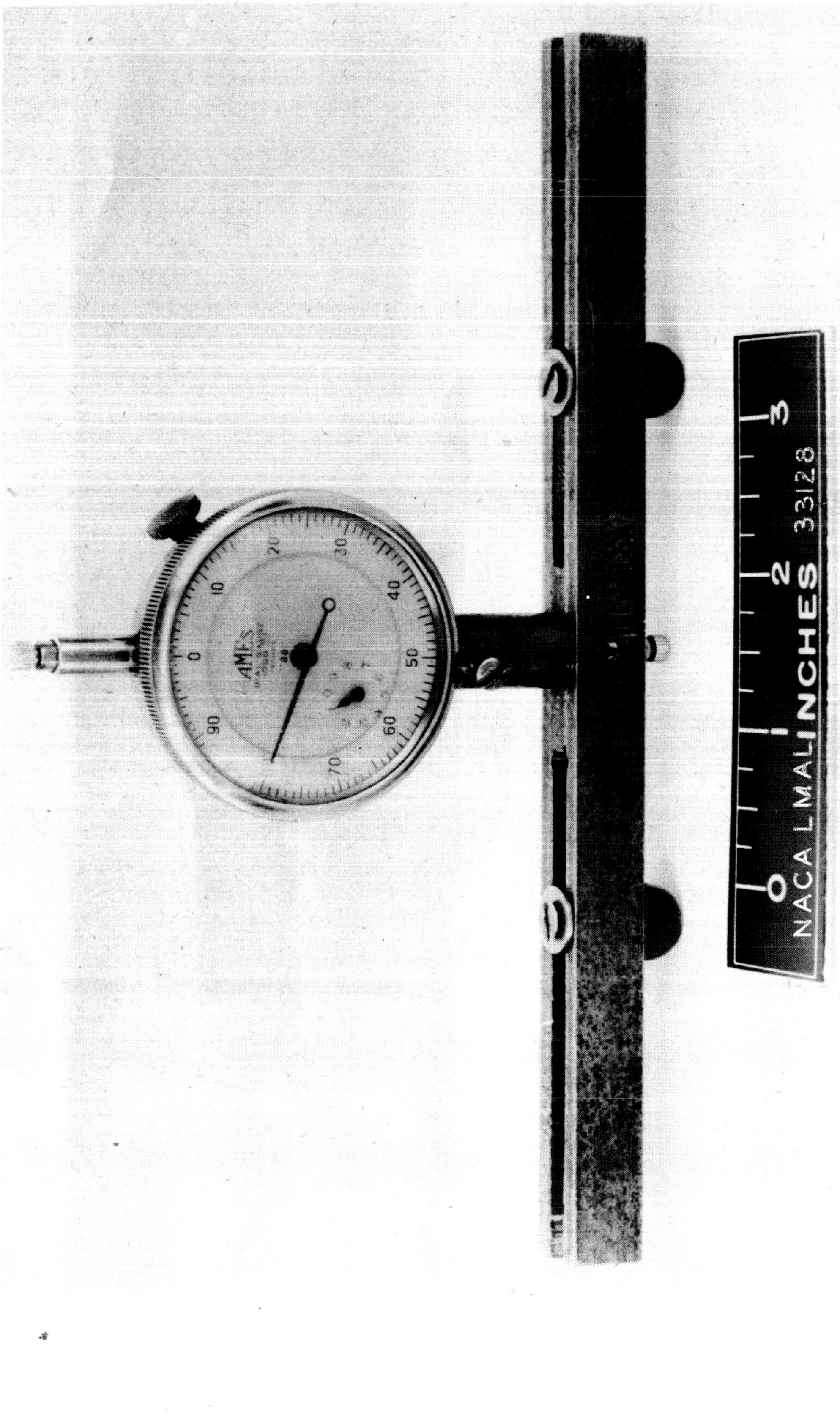

Figure 2.- Curvature gage used in measuring surface waviness.

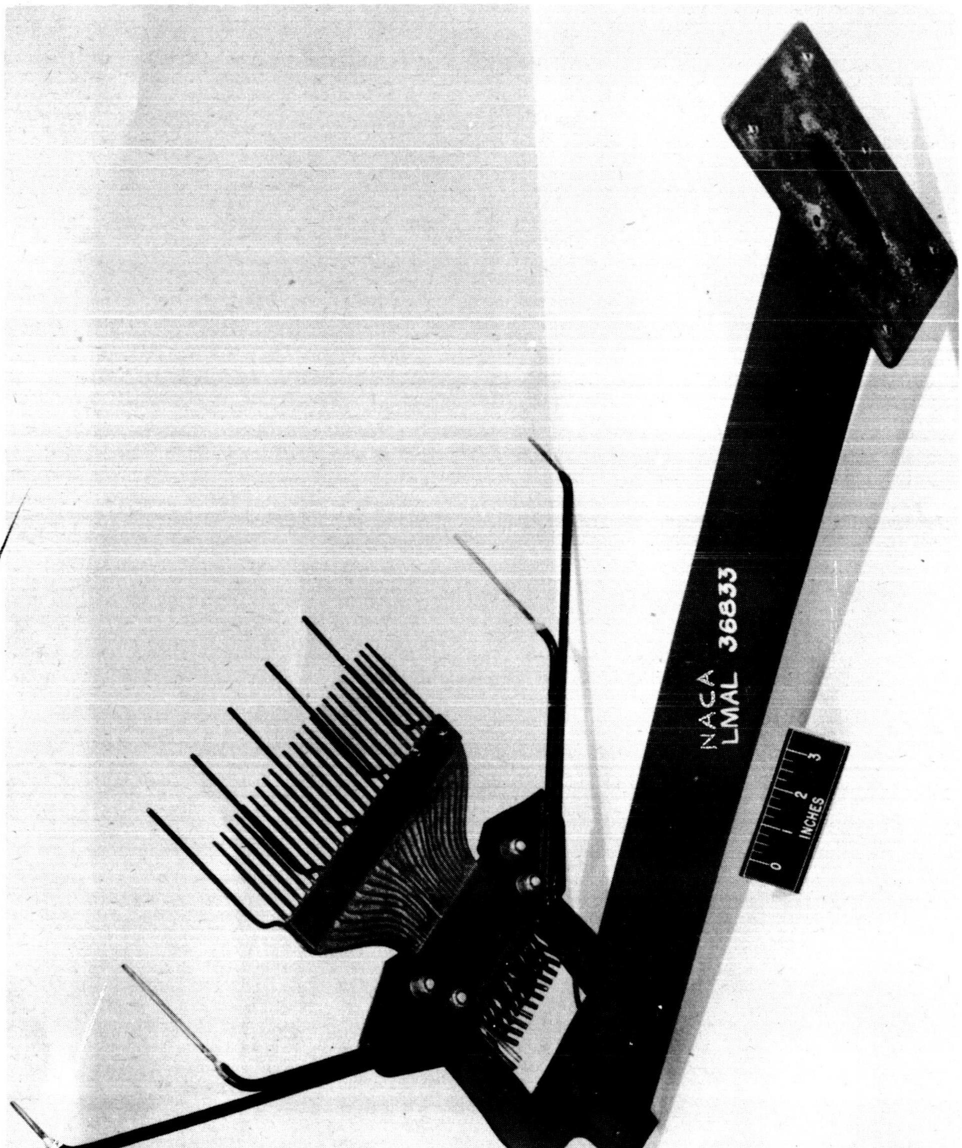

Figure 3.- Wake-survey rake.

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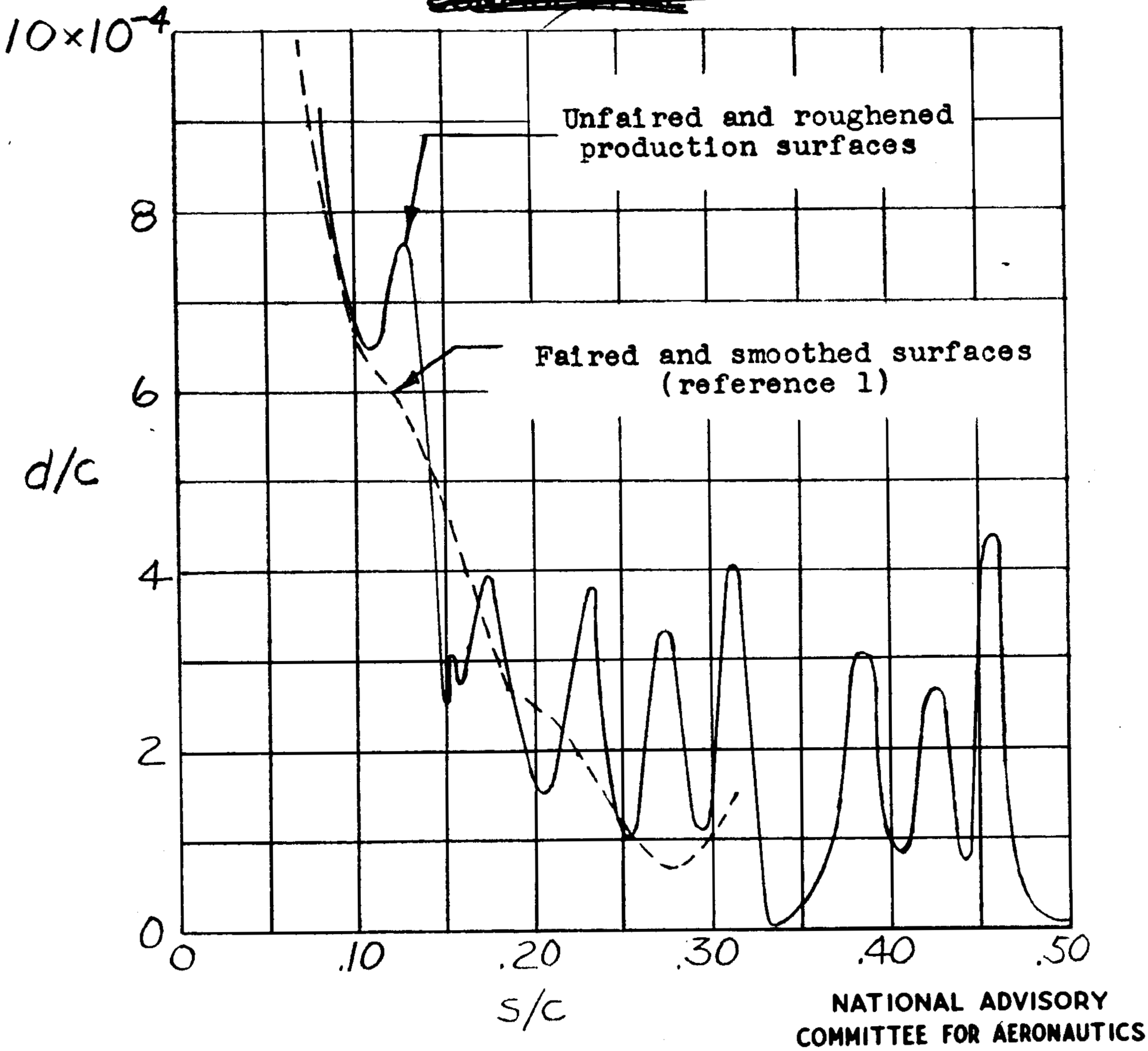

Figure 4.- Surface-waviness index of unfaired and roughened production surfaces and of faired and smoothed surfaces.

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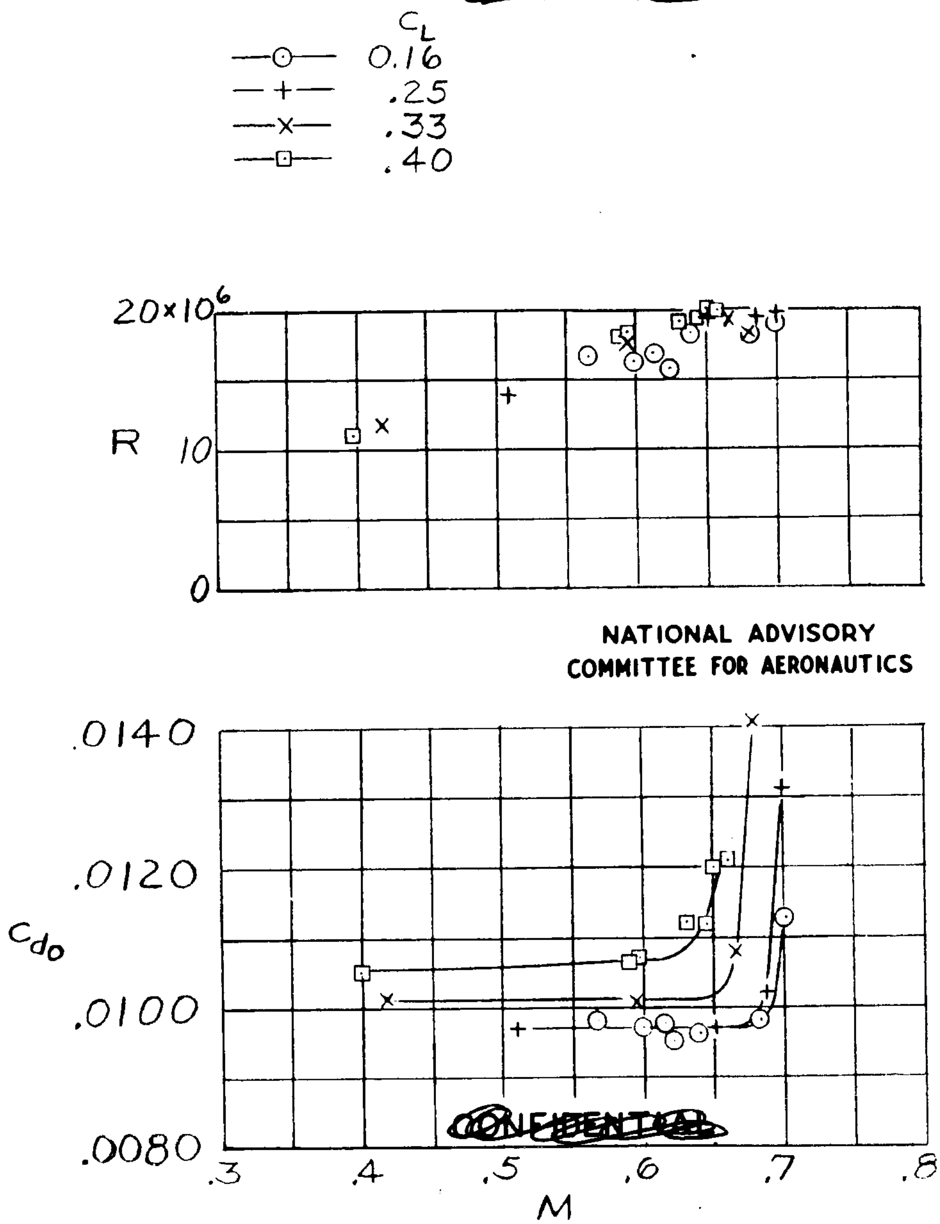

Figure 5.- Profile-drag coefficient of P-47D wing section having production surfaces covered with camouflage paint. Reynolds number is plotted above drag curves.

[redacted]

⊙ No evidence of shock in wake
\+ Evidence of shock in wake
—— First indication of shock in wake
\- - - Critical Mach number for section with faired and smoothed surfaces (reference 1)

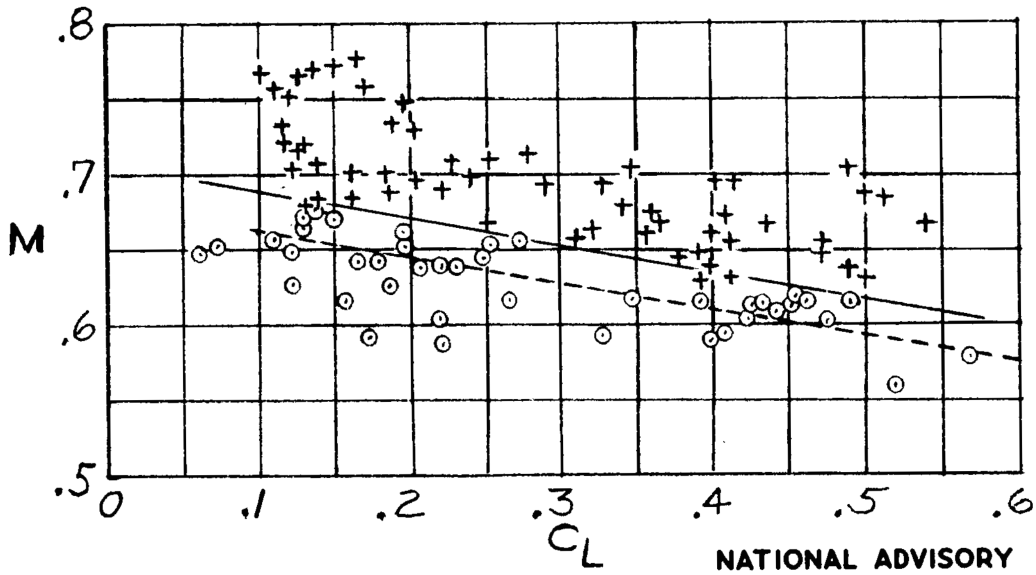

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Figure 6.- Variation with airplane lift coefficient of critical Mach number and Mach number at which shock became evident in wake.

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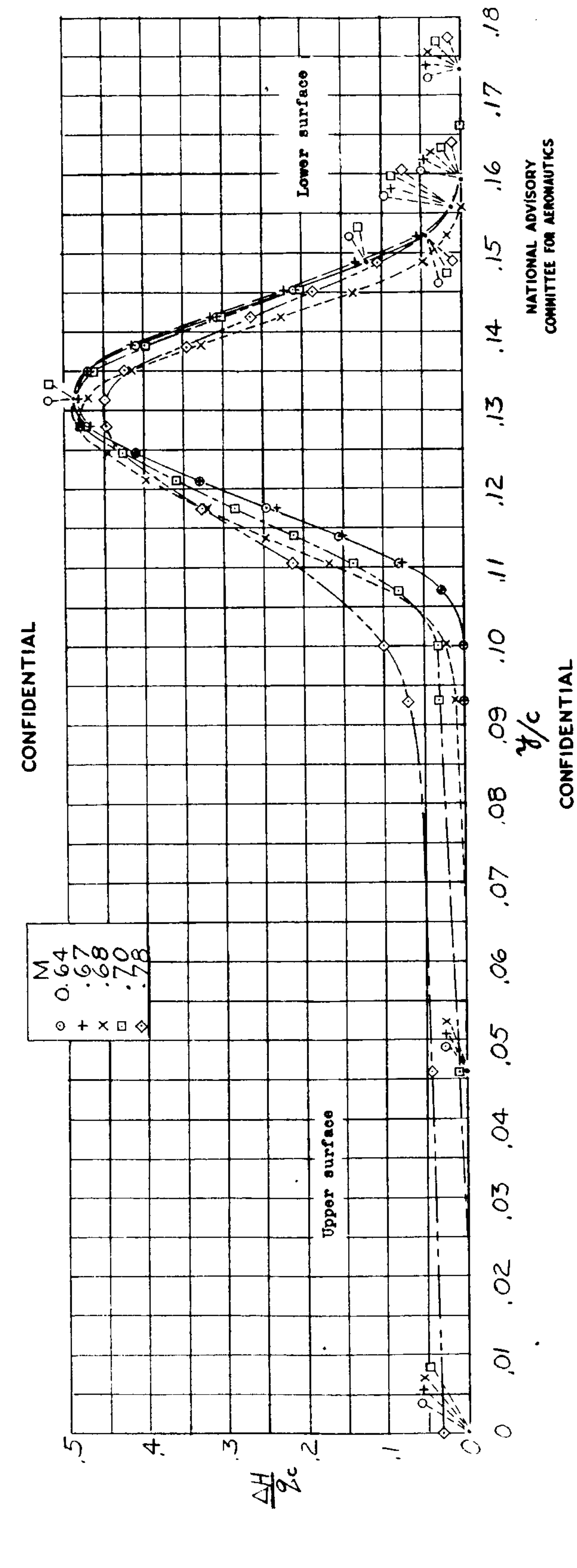

Figure 7.- Wake profiles at an airplane lift coefficient of 0.16 for several Mach numbers. (Position $\frac{y}{c} = 0$ corresponds to top tube in wake-survey rake.)